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ABSTRACT

This paper surveys the area of early childhood numeracy and offers thoughts on best practices in early childhood learning and teaching as it applies to the learning and teaching of numeracy knowledge and skills. Exemplary early childhood numeracy programs are considered against established norms of early childhood learning and teaching, and suggestions for best practices are synthesized. (Contains about 130 references.) (MM)

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Early Childhood Numeracy

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Early childhood numeracy

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Note

This paper was prepared in 1998/1999 and some information in the paper may not reflect more recent developments.

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Contents

Introduction 3

Early childhood and its characteristics 3

Importance of 3–8 age range in children's learning 6

What is numeracy in the early childhood years? 11

Planning and teaching for numeracy in the early childhood years 15

Assessment of numeracy learning in the early childhood years 23

Technology and numeracy in the early childhood years 30

Professional development and initial teacher education in numeracy for early childhood teachers 32

Overall summary 34

References 35

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Introduction

In this paper, I have attempted to survey the area of early childhood numeracy and to offer my thoughts on best practice in early childhood learning and teaching as it applies to the learning and teaching of numeracy knowledge and skills. Exemplary early childhood numeracy programs are considered against established norms of early childhood learning and teaching and suggestions for best practice are synthesised.

The opinions expressed in this paper are solely those of the author and do not necessarily reflect those of the sponsoring bodies. The paper is meant to be provocative as it is only through discussion and argument that progress can be made.

Early childhood and its characteristics

In an internationally accepted definition, 'early childhood' refers to the period of a child's life between birth and eight years of age (Ball, 1994; Bredekamp & Copple, 1997; Organisation Mondiale pour L'Education Prescolaire, 1980; Schools Council, 1992). The definition of the early childhood period equates roughly with the first two stages of cognitive development as described by Piaget (1926; 1928): the sensorimotor stage and the pre-operational stage. While the link to Piagetian stages has resulted in the development of some significant programs, materials and approaches to early childhood education (such as Early Mathematical Experiences in the United Kingdom (Schools Council, 1978) and the Bank Street and High/Scope programs in the United States of America (Cohen, 1972; Hohmann, Banet & Weikart, 1979)), it also has meant that young children, until about age 8, have been considered lacking in logical representational ability and incapable of using logical and abstract thought, resulting in the perception that children in the early years are 'cognitively deficient' (Berk, 1997, p. 232). Challenges to this position have cited the nature and complexity of the tasks employed (Donaldson, 1978; Gelman, 1972; Newcombe & Huttenlocher, 1992) during observations of children's competence in naturally occurring social interactions (Gelman & Shatz, 1978), children's understanding of magic (Rosengren & Hickling, 1994) and other appearance-reality contrasts (Woolley & Wellman, 1990), as well as categorisation (Keil, 1989). A great deal of research relating to young children has indicated that while they have limited cognitive understanding compared with older children, they do demonstrate logical ability in a range of circumstances. Such understanding is likely to develop gradually, hence the early

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childhood period represents a time over which 'children rely on increasingly effective mental as opposed to perceptual approaches to solving problems' (Berk, 1997, p. 235).

In recent years, the emergence of Developmentally Appropriate Practice (DAP) has highlighted the reliance of early childhood programs on the Piagetian model of development. DAP was developed as a response to the practice of 'pushing down' the curriculum, so that formal academic instruction, developed for older, more experienced children, was being implemented with younger and younger children, on the basis that 'the earlier they learnt it the better' (Elkind, 1987). DAP aimed to set out a reasonable level of expectation for children aged birth to 8 years, and encouraged those working with young children to consider appropriate developmental levels and expectations in their planning for learning experiences. However, many early childhood educators were critical of DAP because it seemed to lack an awareness of the cultural and social contexts in which young children's learning occurs (Fleer, 1995; MacNaughton & Williams, 1998).

This focus on the social and cultural contexts of children highlights a growing awareness of the impact of these areas, not only on what children learn, but also on how it is learned and how it is taught. A shift towards a consideration of Vygotskian principles relating to the social mediation of knowledge has prompted a focus not only on what it is that children are capable of on their own (for example, as assessed through Piagetian tasks), but also, what they are capable of achieving with the assistance of more knowledgeable others through scaffolding, and through teachers developing and implementing tasks that target the zone of proximal development (Berk & Winsler, 1995; Bodrova & Leong, 1996; Dockett & Fleer, 1998; Fleer, 1992).

Lists of fundamental principles underlying young children's learning have been developed in the United Kingdom (Ball, 1994), the United States of America (Bredekamp & Copple, 1997) and in Australia (Dockett, 1995). While the wording varies, there is much coherence, as can be seen from the principles of learning in all areas of early childhood which are collated below.

1. The learning which occurs in the early years is important, both in and of itself as well as in relation to future success (Dockett, 1995). Development occurs in a relatively orderly sequence, with later abilities, skills and knowledge building upon those already acquired (Bredekamp & Copple, 1997).
2. Development proceeds at varying rates from child to child as well as unevenly within different areas of each child's functioning (Bredekamp & Copple, 1997).
3. All children have potentials which can (and should be) identified and promoted (Ball, 1994). All children are capable of learning and should be encouraged to regard themselves as competent learners (Dockett, 1995).

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4. Domains of children's development — physical, social, emotional, and cognitive — are closely related. Development in one domain influences and is influenced by development in other domains (Bredekamp & Copple, 1997).

5. Children are active learners, drawing on direct physical and social experience as well as culturally transmitted knowledge to construct their own understandings of the world around them (Bredekamp & Copple, 1997).

6. Children who feel confident in themselves and their own potential have a headstart to learning (Ball, 1994).

7. Development proceeds in predictable directions toward greater complexity, organisation and internalisation (Bredekamp & Copple, 1997).

8. Play and conversation are important means by which young children learn about themselves, other people and the world around them (Ball, 1994). In addition, children learn through social interaction with adults and other children and through teacher-initiated as well as child-initiated experiences (Dockett, 1995).

9. Development and learning occur in, and are influenced by, multiple social and cultural contexts (Bredekamp & Copple, 1997).

10. Development advances when children have opportunities to practise newly acquired skills as well as when they experience a challenge just beyond the level of their present mastery (Bredekamp & Copple, 1997).

11. Children demonstrate different modes of knowing and learning and different ways of representing what they know (Bredekamp & Copple, 1997).

The relationships which children make with other children and with adults are of central importance to their development (Ball, 1994). Children learn most effectively when there is a partnership between parents and teachers, when there is a sense of community between home and school environments (Dockett, 1995) and where they feel safe and valued, their physical needs are met and they feel psychologically secure (Bredekamp & Copple, 1997).

One time in which the importance of these relationships and the need for safety and continuity are highlighted is when the young child starts formal schooling. This can be a time of great excitement and drama as well as a time when the child's social context is changed radically. It is clear that the experiences of children as well as the expectations of teachers, parents and children change as the setting changes (Hadley, Wilcox & Rice, 1994; Margetts, 1997; Perry, Dockett, Clyde & Tracey, 1998; Perry, Dockett & Tracey, in press; Richardson, 1997). These changes can have a marked effect on the children's opportunities, dispositions and potential to learn.

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Early childhood commences at birth. The years before the children commence schooling are critical to all their learning, including their learning of numeracy. In these years, the foundations are laid 'for the children's effective numeracy via play and language development' (personal communication from Dr N. Yelland, Senior Lecturer in Education, Queensland University of Technology).

Importance of 3–8 age range in children's learning

Prior-to-school years

Bredekamp & Copple (1997, p. 97) note that the prior-to-school years are recognised as a vitally important period of human development in their own right, not as a time to grow before 'real learning' begins in school. While there remains a body of research to suggest that children undergo a significant cognitive shift between the ages of about 5 and 7 years (Flavell, Miller & Miller, 1993), resulting in a greater ability to reason in more adult-like ways, it should not be assumed that this ability is totally lacking in younger children. Considerable growth is observed in all areas during the prior-to-school years — and this has relevance to the development of numeracy skills and understandings, particularly when the developing understandings are integrated, rather than separated into specific domains. Growth and development which occur at this time in relation to fine and gross motor skills, understanding and expression of emotional and social competence and developing language capabilities, as well as cognitive changes, have the potential to influence the development of numeracy. Bredekamp & Copple (1997) note that:

> ...as children develop physically... the range of environments and opportunities for social interaction that they are capable of exploring expands greatly, thus influencing their cognitive and social development.... children's vastly increased language abilities enhance the complexity of their social interactions with adults and other children, which in turn, influence their language and cognitive abilities.... Their increasing language capacity enhances their ability to mentally represent their experiences (and thus, to think, reason and problem-solve), just as their improved fine-motor skill increases their ability to represent their thoughts graphically and visually (p. 98).

One of the major issues in early childhood in recent years, and part of the rationale for Developmentally Appropriate Practice, has been the move towards formal academic programs for children in the prior-to-school years. Elkind (1987) has been particularly strong in labelling such forcing of academic programs as *miseducation* Other researchers have noted that young children benefit from being intellectually and perceptually challenged (Katz & Chard, 1989; Edwards, Gandini & Forman,

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1993), by focussing on issues of relevance and interest to them through child-initiated as well as adult-initiated investigations (Dockett, 1998a; Tinworth, 1997), rather than by adhering to a specific academic program which has not been tailored to the specific needs, interests and abilities of the children in a particular group. Such a view does not preclude adult involvement or guidance. Rather, developing a challenging learning environment by targeting learning in the learner's zone of proximal development neccssitates some level of involvement by an adult, or more experienced other.

First years of school

The age at which young children may start school varies across Australia (Senate Employment, Education and Training References Committee, 1996). One result of this is that children in the first years of school are a diverse group — socially, cognitively, culturally, emotionally and in terms of their expectations (Morrison, Griffith & Alberts, 1997). Of course, age is but one of the myriad of reasons for such diversity, although it is one which is seen as important among teachers and educational administrators (Biggs & Potter, 1995; Schools Council, 1992; Senate Employment, Education and Training References Committee, 1996). Starting school is a significant event in the lives of children and their families and it brings with it a range of challenges and changes (Griffin & Harvey, 1995). One of the changes is that, generally, the curriculum within a school setting is structured according to learning or discipline areas. This is in spite of the range of research which suggests that an integrated curriculum for young children is most likely to support the development of meaningful links (and hence transfer) in learning (Bredekamp & Rosegrant, 1992; Caine & Caine, 1994) and helps children establish a depth of understanding that facilitates the development and application of concepts (Krogh, 1995). Numeracy development in the first years of school could provide an integrating factor which might facilitate such links.

While the notion of 'best practice' in children's education is relativistic, early childhood educators seem able to, at least, reach a consensus on what constitutes reasonable or 'good' practice. The Schools Council (1992) noted that 'good practice' in the early years of school depended on:

> seeing the world through each child's eyes, registering objectively their interests and existing competencies, and understanding sufficiently the principles of development to know how to help each child learn effectively, efficiently and meaningfully. Good practice does not permit asking children to learn now, with difficulty, something they will manage more easily later. Nor does it include busy work, the teaching of isolated skills development through memorisation and rote, or a reliance on work sheets (p. 8).

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There is no suggestion from the Schools Council that young children should experience a 'watered down curriculum'. Rather, the suggestion is that effective teaching and learning in this period is based on a sound knowledge of each child and their background, a recognition of their potential and a thorough understanding of the principles of learning which were espoused in the previous section of this paper.

Some early childhood educators suggest that, in Australia, at least, there is a mixture of 'top (or push) down' and 'watered down' curricula apparent in early childhood settings. For example, 'in the first years of school, teachers are highly likely to be influenced by the "push down" curriculum because of the nature of the system... and high parental/community expectations of evidence that the learning of formal concepts is taking place' while 'parental/community/political expectations of the under 5 settings generate a "watered down" curriculum in which there is usually no desire for tangible evidence of a formal conceptual agenda at all' (personal communication from Dr Agnes Macmillan, Lecturer in Education, Charles Sturt University Albury Campus). The end result can be confusion on the part of the teacher and a disjunction as the children move from prior-to-school to school settings. This has particular importance in the area of numeracy development.

Home-school links

The Schools Council (1992) and the New South Wales Department of School Education (1995), among others, have promoted the view that partnerships with parents are an essential element of effective early childhood education. There is evidence that parents and the home exert at least as strong an effect on children's educational outcomes as do schools or teachers. For example, the Schools Council (1992, p. 21) has noted that 'the Coleman report in the United States and the Plowden Report in the United Kingdom asserted that family background and attitude had more to do with a child's school success than input from school'. Studies have shown a positive relationship between parental involvement in their children's schooling and the achievement of these children in areas including numeracy (Brown, 1989; Civil, 1998; Greenberg, 1989; Reynolds, 1992; Young-Loveridge, 1993a; Young-Loveridge, Peters & Carr, 1998). For example, Reynolds (1992) reports that parental involvement:

> appears to represent a way for parents to invest in their children that is independent of parent education and background characteristics. Children may, as a result of their parents' activity in school, develop more confidence in their ability, show greater motivation, and experience a greater sense of cohesiveness with their school that enables them to perform better. Family-school relations may also denote an attitude of optimism among parents that carries over to the children (p. 457).

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Early 'intervention'

In this section, exploration is made of the term 'early intervention' from a general education standpoint. Later in the paper, this discussion will be applied and expanded through consideration of early intervention in numeracy.

There are many connotations of the term 'early intervention'. The Senate Employment, Education and Training References Committee (1996, p. 131) noted that '[I]ntervention carries somewhat authoritarian and patronising overtones which suggest a deficit model of the child and his or her family'. While this concern was expressed in relation to 'early intervention' services for young children with learning disabilities, the same reservation needs to be considered when using the term in relation to young children who are deemed to require additional assistance in specific areas of learning. The Committee further noted that:

> Early intervention must not be construed simplistically as operating out of a deficit model of education — that is, intervention construed solely as redemption. It may have a remedial dimension, but it is also profoundly about ensuring that children will maximise their development during those critical early years (p. 131).

In the early childhood field, the use of the term 'intervention' is often questioned. While there is a recognition that some children may have specific needs which require such intervention, many early childhood educators suggest that the best sort of early 'intervention' is effective teaching. That is, what is needed is 'an orientation to prevention rather than remediation' (Wright, Mulligan, Stewart & Bobis, 1996, p. 299). Later in this paper, a number of programs designed to help develop children's mathematical and numeracy concepts will be considered. Many of these involve an 'intervention' approach but all of them aim to provide effective teaching.

Developmental plasticity and cost-effectiveness are the two planks on which the platform of 'early intervention' is built (Senate Employment, Education and Training References Committee, 1996; Ysseldyke, Algozzine & Thurlow, 1992). The first of these responds to the neuroscientific fact that 'brain connections develop quickly in response to outside stimulation' and that '[A] child's experiences — good or bad — influence the wiring of his brain and the connections in his nervous system' (Newberger, 1997, p. 5). This brain development research leads to the notion of 'critical periods' or 'windows of opportunity' when particular types of learning take place in young children. Consequent upon this is the belief that there are particular periods in the young child's development which are best suited for particular facets of the child's development. 'This notion of developmental plasticity is the justification for an array of early intervention programs for children... the assumption of developmental plasticity directs assessment of young children and the goals of intervention' (Ysseldyke, Algozzine & Thurlow, 1992, p. 260). However, a

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note of warning about reading too much into the neuroscientific basis for early childhood programs has been sounded by some neuroscientists.

> ...[w]e should be wary of arguments that use this neuroscientific evidence in arguments for highly specific early childhood environments, experiences, and policies. Despite what we see in the policy literature and read in the newspapers, as far as this developmental process is concerned, it matters little, if at all, whether the child is at home with Mom or in a Montessori preschool (Bruer, 1997, p. 9).

There are strong arguments for the cost-effectiveness of early intervention programs with young children deemed to be 'at risk', in terms of the avoidance of costs later in the child's life when interventions would need to be more frequent and more intensive to achieve similar results, if, in fact, these can be achieved. For example, in their study of significant benefits of the High/Scope preschool program in the United States of America, Schweinhart & Weikart (1994) note that '[O]ver the lifetimes of the participants, the pre-school program returns to the public an estimated $7.16 for every dollar invested' (p. 98). These returns are calculated in terms of social costs derived from intervention or support which may be required in later years. There is substantial evidence that quality preschool and early school programs have the potential to provide cost-effective strategies for the assistance of 'at risk' young children. However, as always, the quality of these programs is paramount. Early intervention can be successful and cost-effective but only if the programs implemented are of very high quality, reflecting the principles of early childhood learning which have been described earlier in this paper.

Concerns expressed about early intervention include the view that such intervention is only as good as the follow-up that is provided and that short term intervention is often insufficient.

> ... [e]arly intervention can in no way be regarded as some brief tactical incursion into a child's life for the purpose of correcting a developmental fault, or propping up fragile progress. It is the first step — albeit a most crucial one — in a longer program of assistance and support which must be provided by families, carers, specialists and teachers as the child makes the transition from early infancy, through preschool and into the primary years (Senate Employment, Education and Training References Committee, 1996, p.132).

Clearly, early intervention without later support is problematic. Programs such as *Count Me In Too* in NSW which was built on the early intervention *Mathematics Recovery* (Wright, 1996b), *Maths in Schools* in Victoria, in part relying on the work of *Mathematics Intervention* (Pearn, 1998a; 1998b) and *Flying On* in some Tasmanian schools, built upon *Flying Start* (Department of Education, Tasmania, 1997) have all recognised the importance of this quality follow up.

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What is numeracy in the early childhood years?

What is numeracy?

A brief history of the term '*numeracy*' is given in *Numerate students - Numerate adults* (Department of Education and the Arts, Tasmania, 1995), resulting in the following description of numeracy:

> To be numerate is to have and be able to use appropriate mathematical knowledge, understanding, skills, intuition and experience whenever they are needed in everyday life. (Department of Education and the Arts, Tasmania, 1995, p. 6)

In England, the following brief definition of numeracy has become accepted:

> Numeracy is the ability to process, communicate and interpret numerical information in a variety of contexts (Askew, Brown, Rhodes, Johnson & Wiliam, 1997, p. 7)

This is expanded in the final report of the Numeracy Task Force in Britain to the following:

> [N]umeracy at Key Stages 1 and 2 is a proficiency that involves a confidence and competence with numbers and measures. It requires an understanding of the number system, a repertoire of computational skills and an inclination and ability to solve number problems in a variety of contexts. Numeracy also demands practical understanding of the ways in which information is gathered by counting and measuring, and is presented in graphs, diagrams, charts and tables(Department for Education and Employment, United Kingdom, 1998, p. 11).

The key points in all of these descriptions and definitions have been summarised in the report of the Numeracy Education Strategy Development Conference convened jointly in 1997 by the Australian Association of Mathematics Teachers and the Education Department of Western Australia. This conference suggested that:

> numeracy involves... using... some mathematics... to achieve some purpose...in a particular context (AAMT, 1997, p. 13).

and agreed that the following statement should inform future numeracy education:

> To be numerate is to use mathematics effectively to meet the general demands of life at home, in paid work, and for participation in community and civic life.
>
> In school education, numeracy is a fundamental component of learning, performance, discourse and critique across all areas of the curriculum. It involves the disposition to use, in context, a combination of:
>
> - underpinning mathematical concepts and skills from across the discipline (numerical, spatial, graphical, statistical and algebraic);

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- mathematical thinking and strategies;
- general thinking skills; and
- grounded appreciation of context (AAMT, 1997, p. 15).

Such an understanding of numeracy brings together many ideas important in the early childhood context. Clearly, there is a recognition that the sociocultural context of the learner, as well as mathematical concepts and skills, plays a key role in numeracy development. Equally, the learner's disposition to use the mathematics effectively is critical. There is a lot more to numeracy than a set of mathematical knowledge and skills. However, at the early childhood level, such distinctions can become quite blurred.

Relationships and differences between mathematics and numeracy in the early childhood years

It is clear that numeracy and mathematics are simultaneously similar and different (Department of Education and the Arts, Tasmania, 1995, pp. 8–9). This is particularly the case in the early childhood years, where children are beginning to develop their knowledge and skills in mathematics while applying them to their own contexts. For example, a child learning to count will use this to find the answers to questions of 'how many' in many meaningful situations. The development of the knowledge and skill go hand-in-hand with their application. On the other hand, a child reciting the standard forward number word sequence may simply be reciting 'a poem' formed by the number words and may have no intention or no context in which to use this knowledge. We have moved beyond statements such as '[N]umeracy is basic competence in mathematics' (Mannigel, 1992, p. 35) to a realisation that the principles of early childhood education require that mathematics provides the procedural and conceptual basis for numeracy, with the 'using of the mathematics' the reason for learning it as well as the mode for learning it.

However, even at the early childhood level, numeracy goes beyond mathematics, as children, for example, strive to satisfy all of their friends by sharing out their lollies evenly to thus avoid social turmoil, or by using timers to ensure that children playing with a computer program can be assured of having a fair turn. The application of mathematics to a contextual problem or challenge confronts young children throughout their day in prior-to-school settings, home, shopping centres and schools, to name just a few contexts. To solve these problems and meet the challenges, young children need not only to have developed their mathematical skills and knowledge but their dispositions and self-confidence so that they are willing to apply these in novel situations.

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The contextual learning and integrated curriculum apparent in many early childhood — particularly prior-to-school — settings means that differences between the development of mathematics and numeracy can be small. Just as mathematics is learned 'in context' so it is used 'in context' to achieve some worthwhile purpose. While the differences between mathematics and numeracy may become larger as the learners move through the school system, there is a sufficiently early childhood approach to learning in many classrooms in the first years of school to suggest that the contextual learning of mathematics and numeracy can go hand-in-hand.

Relationships and differences between literacy and numeracy in the early childhood years

While there has been a historical link between literacy and numeracy and, even, some attempt to suggest that literacy includes numeracy, it seems clear that the foundation on which numeracy is built — mathematics — is clearly not the same as the foundation on which literacy is built. Even at the early childhood level, this distinction remains valid, in spite of the curriculum integration with its focus on the 'whole child' rather than specific discipline areas (Arthur, Beecher, Dockett, Farmer & Death, 1997).

In spite of this distinction, there is clearly an important role for literacy in numeracy development, both in terms of the language of mathematics and numeracy and the use of language in the children's contextual problem solving. Examples include the role of language in the learning of mathematical vocabulary and the importance of language in the assessment of numeracy development. There is little doubt that language and mathematics development are mutually supportive (Ellerton & Clements, 1996; Pengelly, 1990) and this is continued in links between literacy and numeracy. Nonetheless, the mathematical foundations on which numeracy are built are clearly different from the linguistic foundations of literacy.

Early 'intervention' in numeracy

In Section 2 of this paper, the notion of early 'intervention' was explored in general. When this notion is applied to numeracy at the early childhood level, we find that there is very little evidence for or against such 'intervention'. Partly, this is because of the reluctance of the early childhood field to distinguish between early 'intervention' and effective teaching in the early childhood years. Partly, it is because of the reluctance of the early childhood field to recognise that there is a place for early numeracy development in the prior-to-school years. As one of the critical friends for this paper has put it:

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> [T]he implication is that children could be 'at risk' with their future numeracy development if specific instructional teaching programs are not undertaken in the prior-to-schooling contexts. The term 'intervention' implies that the experiences are not naturally occurring events integral to the child's play or other informal learning experiences. Rather, I see the facilitation of early numeracy development as a matter of awareness for those responsible for young children — for them to be able to recognise where and how the mathematical dimensions are already present in many purposeful everyday (or imaginative play) experiences. In other words, it's not really a matter of *MORE* or *OTHER* (though maybe some of this could be appropriate in some environments) but a matter of *HOW* to encourage access to and appreciation of mathematical concepts and skills which are interesting and meaningful to children in whatever contexts they find themselves (personal communication from Dr Agnes Macmillan, Lecturer in Education, Charles Sturt University - Albury Campus).

The importance of the children's social context is emphasised also by the Queensland School Curriculum Council in their 'Preschool curriculum guidelines':

> ... numeracy development is influenced by the children's social and cultural contexts. Differences in the understanding developed within these contexts should not be viewed as deficits or advantages but as different sets of experiences upon which teachers can build (Queensland School Curriculum Council, 1998, p. 58).

On the other hand, there has been some work, dubbed as intervention studies in early numeracy, which claims to show the value of specifically targeted approaches in numeracy and mathematics development (Pearn, 1998a; 1998b; Peters, 1993; Wright, Stanger, Cowper & Dyson, 1996; Young-Loveridge, 1993a, 1993b; Young-Loveridge, Carr & Peters, 1995). For example, Young-Loveridge (1993a; 1993b) has compared school-based intervention, home-based intervention and no intervention with classes of 5 year olds in New Zealand and has found that the effects of the school-based intervention were large and were maintained for at least 15 months after the intervention, while the home-based intervention was less successful, both in terms of the size of gains and their maintenance. It is important to note that the school-based intervention reported here involved intensive intervention of 30 minute classes each day for seven weeks and was based on number rhymes, stories and games, thus reflecting some of the approaches which have been described earlier as appropriate in early childhood settings.

Wright and his colleagues (Wright, Stanger, Cowper & Dyson, 1996) have reported progress for children involved in their *Mathematics Recovery* program and have shown that this progress is maintained over later years. Once again, the *Mathematics Recovery* program is resource-intensive — both in time and personnel — but it does seem to be producing the desired results.

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Whether or not these two examples are dubbed early 'intervention' programs or are simply categorised as effective teaching is a moot point and probably of very little importance in the long run. What is clear is that there are some programs in Australasia which seem to be able to help young children develop their mathematics, and, hence, their numeracy, potentials.

Planning and teaching for numeracy in the early childhood years

Introduction

In this section of the paper, the crux of the issue of numeracy in the early childhood years will be addressed. We ask 'What is it that needs to be done in order for young children to develop appropriate numeracy behaviours?' and we answer this through reference to current research and practice in Australia and overseas.

Prior-to-school years

It has generally been accepted that certain mathematical knowledge and skills are desirable outcomes of children's prior-to-school experiences, whether they be in the home, in a child care centre or in some other context. However, the nature of early childhood curricula in prior-to-school settings, as has been outlined in previous sections, is such that it is difficult, and often seen as inappropriate, to separate these mathematical ideas from other knowledge and skills which are being developed by the children. In many ways, this fits well with the numeracy agenda in that it ensures the application of the developing mathematical knowledge and skills in a meaningful context for the learners. This is very well illustrated in the document *Foundation areas of learning* (Department for Education and Children's Services, South Australia, 1996).

As a direct consequence of this 'early childhood approach' to an integrated curriculum, there have been very few attempts to articulate an approach to numeracy in prior-to-school settings. In many such settings, it may not be appropriate or feasible to do so.

The first years of school

In spite of the espoused adherence to many of the principles stated in earlier sections about an early childhood approach to education, the first years of school, particularly

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in areas such as mathematics, have both suffered and benefited from the downthrusting of curriculum content and approaches from the later years. The rush into formalisation, the apparent need for all young children to write and talk in the 'proper' mathematical language and the need for these children to acquire numerous disconnected pieces of information — information disconnected within itself and certainly disconnected from the children's contexts, particularly, in many cases, their social contexts — have resulted in not only poor learning but in learners who are disaffected by the learning of both process and content (Pengelly, 1990; Perry, 1979). Too little cognisance of the children's own strategies, approaches and dispositions has been taken in the past (Mulligan & Mitchelmore, 1996a; Perry & Conroy, 1994; Wright, 1996a; Yackel & Cobb, 1996). This seems to be changing, with the emergence of projects about learning and teaching mathematics, and applying it to the children's own contexts. The recognition that learning and applying mathematics is not an individual sport but requires the active participation of the learner and the teacher within a community of inquiry has resulted in many exciting programs. Some of these projects will be highlighted later in this section.

Home-school links

The importance of links between home and school in young children's mathematics education has long been recognised in Australia (Australian Education Council, 1991b; Commonwealth Schools Commission, 1987; Perry & Barry, 1985). Each of the exemplary programs which are discussed later in this section recognises the importance of these links. While there is a great deal of recent research about the importance of links between home and school (for example, Parr, McNaughton, Timperley & Robinson, 1993; Reynolds, 1992), the situation is summed up, in spite of its poorly weathered language, in the following classic piece:

> Parents want to help their children learn. When children are in their first years of school, we know that parents are especially important. Teachers want children to do well. Parents want children to do well. People have done a lot of research which shows over and over again, that when home and school work together, children have the best chance of being good at schoolwork (Winder, 1987, p. 1).

Prior-to-school experiences

In 1978, a set of booklets, entitled *Early mathematical experiences* (Schools Council, 1978) was published in the United Kingdom. These grew out of the *Nuffield Mathematics Project* which was so influential during the 1960s and 1970s. In many ways, this publication represented the first attempt to systematically document appropriate practices, based on Piagetian epistemology, for the development and

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application of mathematical knowledge and skills in the prior-to-school years. Because of its emphasis on the contextual development and application of mathematics, it is justifiably claimed that this represents one of the first attempts to address numeracy in the prior-to-school years. It is also worth noting that nothing of this scope has been attempted again in the intervening 20 years, in spite of the massive increase in our knowledge about children's learning — and their mathematics learning in particular — over this period. It is time for it to be attempted again and it is one area in which Australia could take world leadership because of the expertise it enjoys in both the early childhood and mathematics education fields.

Current programs to develop numeracy knowledge and skills in children prior to their school years include Te Whaariki: *Early childhood curriculum in New Zealand* (Ministry of Education, New Zealand, 1996; Young-Loveridge, Peters & Carr, 1998), the Singapore preschool syllabus (Sharpe, 1998), *Flying Start* in Tasmania (Department of Education, Tasmania, 1997), *Preschool Curriculum Guidelines in Queensland* (Queensland School Curriculum Council, 1998), and the *Foundation Areas of Learning* in South Australia (Department for Education and Children's Services, South Australia, 1996). In all cases, these programs are established in line with the characteristics of appropriate early childhood practice which emphasise the importance of learning evolving as naturally as possible from children's social contexts. They recognise the importance of activity, relevance and social context to the children's numeracy learning and strive to work in collaboration with the children's home setting. They recognise the integrated nature of children's learning in the prior-to-school years and use this to strengthen their approaches to numeracy development. While numeracy is a key component of each of these approaches, it does not form the major emphasis of any of them due to the integrated nature of curricula in prior-to-school settings. In fact, there is evidence to suggest that comparatively little specific mathematics instruction occurs in the prior-to-school years and most of that is incidental (Young-Loveridge et al., 1998). Many early childhood educators, including the current author, would feel that this is the way it should be.

School

In the early years of school, approaches to numeracy development abound, reflecting the importance placed by educators and curriculum developers on both early intervention (Gaffney, 1994; Ysseldyke, Algozzine & Thurlow, 1992) and new developments in brain research highlighting critical periods or 'windows of opportunity' for learning (Bruer, 1997; Newberger, 1997). Key examples of programs in the early years of school are: the *National Numeracy Strategy* in the United Kingdom (Department for Education and Employment, United Kingdom, 1998),

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Count Me In Too in NSW (New South Wales Department of Education and Training, 1998a; Stewart, Wright & Gould, 1988; Wright, 1998); *Mathematics Intervention in Victoria* (Pearn, 1998a; 1998b) and *Flying Start* in Tasmania (Department of Education, Tasmania, 1997). It is tempting to enter into a debate about whether or not these are programs in numeracy or mathematics development. However, in view of the integrated early childhood approach one hopes would be adopted in the early years of school, as well as in the prior-to-school settings, this seems fruitless. Even realising that this ideal is not always reached does not defeat the opportunity provided in the early years to develop mathematics and numeracy hand-in-hand. Many of the programs to be investigated aim to do this.

National Numeracy Strategy, United Kingdom

It is fair to say that the placement of this program under a heading of 'best practice' could be questioned (and has been by some of those whose advice has been sought in preparing this paper). Nevertheless, this program has the potential to impact strongly on practice in Australia and does need to be studied. The key points in the approach to numeracy education in primary schools recommended by the final report of the United Kingdom Numeracy Task Force include:

- teaching all... pupils a daily 45 to 60 minute mathematics lesson;
- teaching mathematics to all pupils within a class at the same time, with a high proportion of lessons concentrating on the development of numeracy skills;
- teaching mathematics to the whole class or to groups for a high proportion of the lesson, promoting participation from, and co-operation between, pupils;
- including oral and mental work within each daily mathematics lesson; and
- providing regular mathematical activities and exercises that pupils can do at home (Department for Education and Employment, United Kingdom, 1998, p. 16).

The report goes on to specify what it sees as a typical lesson within the approach. This typical lesson, while on the surface seeming to match much of the approach espoused by the Purdue Mathematics Group (Cobb & Bauersfeld, 1995), in fact relies much more on the notions espoused by proponents of 'explicit teaching' (for example, Westwood, 1995). The report does suggest that teachers 'should use their professional judgement to determine the activities, timing and organisation in each part of the lesson' (Department for Education and Employment, United Kingdom, 1998, p. 19), although it is clear that the expectation is for conformity with the recommended model.

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The Numeracy Task Force sees that 'mental calculation methods lie at the heart of numeracy' and that, '[t]hey should be emphasised from an early age' (Department for Education and Employment, United Kingdom, 1998, p. 51). Moreover, it is 'agreed that the use of calculators should be limited, particularly for younger pupils' (Department for Education and Employment, United Kingdom, 1998, p. 52). These statements will be welcomed by the Australian proponents of mental calculations (for example, Cooper, Heirdsfield & Irons, 1996; McIntosh, 1996) and will not surprise those who have spent a great deal of their professional lives investigating the role of calculators in mathematics education (for example, Stacey & Groves, 1996; Welsh, 1992).

For this author, one of the most telling features of the Numeracy Task Force report is its characterisation of the purpose of the prior-to-school years. Given the broad status and importance given in previous sections of this paper to these early years, it is difficult to agree with the statement that:

> [T]he most important experience that pre-school education can give is to prepare children for learning, in particular, training them to listen closely, to concentrate for reasonable periods, to respond quickly, to sit still when necessary and to value the contributions of other children' (Department for Education and Employment, United Kingdom, 1998, p. 66).

This seems to reject the notion that the early years of a child's life, and education in these years, has value in its own right, that school communities might give some thought to how they might adapt to the children coming to them, as well as having the children adapt to them, and that these school communities might consider the individual needs of their children. A great deal of the work which has been done in studying children's transition to school suggests that schools need to be made 'ready for the children' as well as the children being made 'ready for the school' (Kagan, 1992; Perry, Dockett, Clyde, & Tracey, 1998; Perry, Dockett, & Tracey, in press).

In the author's opinion, it is most appropriate that the situation in Australia has not adopted the United Kingdom model which does little to achieve an early childhood approach to numeracy development, even though there are some features which could be attractive, particularly in terms of the overall approach to assessment which is discussed later in this paper. Instead, there are a number of excitingly positive approaches to the numeracy of our young children, or, at least, to the mathematical underpinnings of this numeracy, some of which will now be considered.

Count Me In Too, New South Wales

This program is a system-wide intervention in early numeracy which is currently operating across New South Wales Department of Education and Training primary schools. It is based on sound research conducted over many years, particularly by the Australian mathematics educators Bob Wright and Joanne Mulligan (for example,

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Mulligan & Mitchelmore, 1996b; Mulligan, 1998; Wright, 1996a; 1996b; Wright, Stanger, Cowper & Dyson, 1996; Wright, 1998) and others (Steffe, Cobb & von Glasersfeld, 1988; Steffe, von Glasersfeld, Richards & Cobb, 1983). The program is based on the learning framework in number, developed from this research and on an explicit set of principles:

- the teaching approach is problem-based. Children are routinely engaged in thinking hard to solve arithmetical problems which, for them, are quite challenging.
- teaching is informed by an initial comprehensive assessment and on-going assessment as part of the teaching process. The latter refers to the teacher's informed understanding of the child's current knowledge and problem-solving strategies, and continual revision of this understanding.
- teaching is focussed just beyond the cutting-edge of the child's current knowledge.
- teachers exercise their professional judgement in selecting instructional settings and tasks appropriate to the needs of their students. These tasks are varied on the basis of on-going observations.
- the teacher understands children's arithmetical strategies and deliberately engenders the development of more sophisticated strategies.
- teaching involves intensive, on-going observation by the teacher and continual fine-tuning on the basis of observation.
- teaching supports and builds on children's intuitive, verbally-based strategies and these are used as a basis for the development of written forms of arithmetic which accord with the children's verbally-based strategies.
- the teacher provides children with sufficient time to solve a given problem. Consequently, children are frequently engaged in episodes which involve sustained thinking, reflection on thinking as well as the results of thinking.
- teaching supports children gaining intrinsic satisfaction from their problem solving, their realisation that they are making progress, and from the verification methods they develop (New South Wales Department of Education and Training, 1998a, Foreword).

Key features of the *Count Me In Too* program are its assessment regimes, including the Schedule for Early Number Assessment, and its professional development component. It honours the characteristics of early childhood learning and teaching through its provision of challenge for the children and recognition and use of their developing numeracy strategies. It is characterised by a constructivist epistemology and certainly questions the notions of developmentally appropriate practice through this recognition of the need for challenge within a supportive environment.

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Mathematics Intervention, Victoria

This program of withdrawal for Year 1 children deemed to be 'at risk' in their mathematics learning was first implemented in 1993 in one Melbourne school. It has subsequently spread to many Victorian schools, partly through its links with the professional development program *Maths in Schools* (Mathematics Association of Victoria, 1996) and has achieved great success (Pearn, 1998a; 1998b). The program has similar bases to the *Mathematics Recovery* approach pioneered in NSW (Wright, 1996b) and:

> offers students the chance to experience success in mathematics by developing the basic concepts of number upon which they build their understanding of mathematics. Students are withdrawn from their classes and work in small groups with a specialist teacher to assist with the development of their mathematical skills and strategies' (Pearn, 1998a, p. 2).

As with *Count Me In Too*, *Mathematics Intervention* is underpinned by a learning framework based on extensive research about children's early number learning (Gray & Tall, 1994; Steffe, Cobb & von Glasersfeld, 1988; Steffe, von Glasersfeld, Richards & Cobb, 1983) and 'requires teachers to use a clinical interview to assess the extent of the child's mathematical knowledge' (Pearn, 1998a, p. 4). While this program is not yet as widespread in Victorian schools as *Count Me In Too* is in New South Wales, the soon to be implemented *Early Numeracy Research Project* in Victoria may serve to stimulate such a growth.

Flying Start, Tasmania

As well as the prior-to-school components discussed earlier, the *Flying Start* program, which commenced in 1997, focuses on numeracy development in the early years of school. While the program is designed to assist all students, it does this by targeting individual students through an explicit teaching cycle of assessment, planning, intervening, monitoring, recording and reporting. *Flying Start* resource teachers are provided in every primary school in Tasmania to reduce the pupil-teacher ratio for a period of every day and to allow the class and resource teacher to work as a team. A number of action research projects has grown from the program and there is an extensive evaluation program currently being undertaken by the Office of Educational Review. There is an extensive and obligatory professional development program associated with *Flying Start*. Anecdotal evidence from teachers suggests that they feel the program has been successful because they are now much more aware of areas on which they need to focus and have strategies to do this. They seem to be more confident about what they are doing in numeracy development and can articulate the basis for this. The program has also helped schools in their development of links with parents.

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All of the programs mentioned here address the affective issues which are so much part of numeracy learning. In all cases, the aim is not only to develop appropriate skills and knowledge but also the confidence and dispositions in the children to encourage them to apply these in contextual numeracy challenges or problems. Games form an integral part of all the Australian programs discussed, recognising the importance of play in young children's learning.

The integrated nature of curriculum in the early childhood years, especially in the prior-to-school settings (Bredekamp & Rosegrant, 1992; Caine & Caine, 1994; Krogh, 1995; Sharpe, 1998), encourages the application of children's mathematical knowledge in a number of different contexts (Department for Education and Children's Services, South Australia, 1996; Department of Education, Tasmania, 1997; Ministry of Education, New Zealand, 1996; Queensland School Curriculum Council, 1997). As the children get older, this approach is weakened in favour of a more subject-based organisation of the curriculum. This is reflected in the specifically mathematical nature of the school programs discussed, even though all of them recognise and facilitate the application of the children's numeracy knowledge and skills in a variety of contextual areas. However, it is reasonable to suggest that Australian systems still have some way to go if they are serious about the development of genuine numeracy programs in both prior-to-school and school contexts. Most of those mentioned above have much stronger claims to be mathematics rather than numeracy programs because they lack the contextualisation which is so important if students are to use '... some mathematics... to achieve some purpose... in a particular context' (AAMT, 1997, p. 13).

Summary

The elements of 'best practice' which can be drawn from this section and the programs described here include the following:

- regular observation of children's existing knowledge, skills and understandings;
- building upon this existing knowledge to provide opportunities to challenge the children's thinking;
- facilitating success for individual children by linking their learning experiences to their context;
- focussing on children's areas of potential, thus aiming for the children to feel satisfied;

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- having access to teachers who know what to expect in terms of children's mathematical development and who are adept in facilitating the children's use of increasingly sophisticated strategies;
- a daily time allocation for the learning and teaching of mathematics and numeracy integrated within the overall educational program.

Assessment[1] of numeracy learning in the early childhood years

The definition and purpose of numeracy assessment in the early childhood years

Assessment is an integral part of all learning. Teachers who are responsible for the facilitation of learning are also responsible for the valid assessment of this learning. There are a number of perspectives which can be brought to bear on this task.

> Assessment is the comprehensive accounting of a student's or group of students' knowledge. Assessment is a tool that can be used by a teacher to help students attain the goal of a curriculum. Assessment, and its results, are not — and should not be interpreted as — the end of educational experiences; instead, as a means to achieve educational goals. Different purposes are served by assessing students' knowledge in the mathematics classroom — measuring students' understanding and use of content, obtaining instructional feedback, grading, and monitoring growth in mathematical achievement (Webb, 1993, p. 1).

> Being a good teacher requires continual information on the progress of one's students; that is, what have they learned in their classroom lessons and what can be expected from them in the future (van den Heuvel-Panhuizen & Gravemeijer, 1993, p. 54).

> Assessment is an integral part of the learning process. Indeed, the major purpose of assessment is the improvement of learning. Assessment provides feedback about students' mathematical development to students and their teachers. This feedback should inform the future action of both learners and teachers. Assessment can also be used to report students' progress to parents, prospective employers, and other educational agencies (Australian Education Council, 1991a, p. 21).

[1] The term 'assessment' is used here because of its more general educational use to indicate the gathering of information about individuals. In some prior-to-school contexts, 'evaluation' is the preferred term for this activity but, in more general contexts, 'evaluation' refers mainly to programs rather than individuals.

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In summarising these statements, this paper will use the definition of assessment contained in the National Council of Teachers of Mathematics *Assessment standards for school mathematics*

> assessment is... the process of gathering evidence about a student's knowledge of, ability to use, and disposition toward, mathematics and of making inferences from that evidence for a variety of purposes (National Council of Teachers of Mathematics, 1995, p. 3).

This definition is not specific to 'early childhood' numeracy or mathematics. The application of the definition is considered in the next section.

The nature of numeracy assessment in the early childhood years

While assessment of numeracy in the early childhood years needs to address the characteristics discussed above, it also needs to address the more general characteristics of exemplary early childhood practice. In particular, there is a need for the assessment to recognise the children's particular needs and contexts. One of these which can be critical is the children's language abilities (Ellerton & Clements, 1996; Newman, 1983). The forms of assessment used and the ways in which they can be administered should reflect these abilities while, at the same time, trying to develop them (Bickmore-Brand, 1990). In the prior-to-school years, assessment is seen as a seamless part of learning, undertaken mainly informally through observation and conversation while the children undertake their normal, self-chosen activities.

Before any assessment task is given to a child or group of children, the teacher needs to be clear about a number of things, if the assessment is to adhere to the principles espoused by good practice. Teachers need to know:

- why they are assessing the numeracy knowledge or skills of their children;
- what knowledge or skills they are going to assess;
- for whom they are assessing — we would like to think that this is usually the children but sometimes it is the state education authority, the program developers, the school principal or the parents;
- how they are assessing the knowledge and skills; and
- when the assessment will take place.

These questions are interrelated in such a way that the answer to one of them may determine the answer to subsequent ones. For example, if what is required is standardised data on children's numeracy performance in Year 3 which will allow results for all the children in a given State to be compared against previous years and within itself, then we may find that what is appropriate is a basic skills test very

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much like that currently being used in New South Wales (New South Wales Department of Education and Training, 1997). If, however, a teacher in a prior-to-school setting is interested in assessment information which will help plan for future activities in the development of early number, it could be that observations of the children at play may be the most suitable method of assessment (Arthur et al., 1997; Perry & Conroy, 1994). On the other hand, the *Third International Mathematics and Science Study* (TIMSS, 1998), provided information on how States and Territories compared in terms of their students' performance on particular tests, thus facilitating political decisions at the level of these systems.

Dockett (1998b) raises a number of issues about assessment, in general, in the early childhood years, which are quite pertinent to the assessment of numeracy in these years. She notes that such assessment is rarely objective, with the biases, expectations and beliefs of the assessor clearly affecting the outcome. One way in which this is manifested is through 'philosophical congruence' (p. 5) — the idea that our philosophy of learning and teaching will be reflected in our assessment. While, in general, this has to be seen as an appropriate situation, it may lead to a teacher being philosophically opposed to an assessment procedure which may be of great benefit to the children's learning. An example is the opposition found among early childhood teachers to 'testing' of children's numeracy or other knowledge and skills through written class tests. However, perhaps with some variation on the types of tests offered, there may be great value in even such a strongly opposed technique. Van den Heuvel-Panhuizen & Gravemeijer (1993) suggest that:

> ... tests need not function only marginally in the instructional process but can be integrated into the curriculum. Tests not only help students create clever strategies but also can help teachers gain a better understanding of what children are able to do. Finally, they help teachers develop richer didactics. This implies reversing the usual thinking about the role of tests in innovation. Rather than thwart innovations, tests can contribute to improving education (p. 64).

While there may be situations where testing of children is appropriate, this will not always be the case. In particular, 'one-off' testing is usually poorly matched to the ways in which children grow, learn and develop. McAfee & Leong (1997, p. 7) note that 'some children may suddenly "put it all together" and achieve unexpected insights. Some children progress in tiny increments that few tests are sensitive enough to detect, yet the progress is real and significant for that child.'

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Australian and international best practice in numeracy assessment[2]

All of the programs described under *Planning and teaching for numeracy in the early childhood years* earlier in this paper recognise the central role played by assessment in their programs and have specific procedures or suggestions for the assessment of children's numeracy knowledge and skills. While each program suggests a variety of assessment methods, there have been some particularly appropriate approaches devised.

National Numeracy Strategy, United Kingdom

This program recognises that '[T]he effective use of assessment has been shown to make a significant impact in raising the standards of attainment overall' (Department of Education and Employment, United Kingdom, 1998, p. 59) but does not specify a particular assessment regime. Rather, it is:

> ... concerned that all assessment should be purposeful, manageable and informative... Pupils need to be well informed about their strengths and weaknesses and, wherever practical, assessment procedures should involve the pupils themselves. It is important that teachers spend time with pupils discussing their progress in mathematics. Talking to individuals, pairs or small groups of pupils each term allows teachers and pupils alike to review progress and set new goals. This approach motivates pupils to take an active role in their development by judging their own progress and recognising their success over time (Department of Education and Employment, United Kingdom, 1998, p. 60).

While the author of this paper has major misgivings about the overall National Numeracy Strategy in the United Kingdom, the assessment procedures outlined in this quote do introduce a refreshingly child-centred approach to assessment. In the development of children's numeracy, such an approach fits well with the overall focus of early childhood teachers on their children's individual needs.

The National Numeracy Strategy encourages testing of students' oral and mental mathematics as well as their written work. It also recognises that there is a great deal of standardised data on children's mathematical performance available from the statutory tests given at the end of Key Stage 2 and suggests that this be used to assist in the development of the children's numeracy learning.

Count Me In Too, New South Wales

A key component of the *Count Me In Too* program is the Schedule for Early Number Assessment, or SENA. This is an individual clinical interview based on the Learning Framework in Number and is designed to be administered by the classroom teacher. The SENA reflects the program through its specific questions about the critical steps

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[2] This paper was prepared in 1998/1999 and some information in the paper may not reflect more recent developments.

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in children's development of number skills and concepts. It gives the teacher a detailed view of what each child in the class can do as well as leading the teacher through the stages of the Learning Framework. While the SENA is quite time consuming to administer, especially for a classroom teacher, the results of its use in classrooms across the State have shown how important it is seen to be for the teachers, both in terms of their access to the thinking of their children but also in terms of its use in illustrating the mathematical ideas which are so critical to the program. The SENA is also a central part of the professional development approach incorporated in the program.

It is important to note that the SENA is not the only assessment technique recommended to be used in *Count Me In Too*. Teachers are reminded of the importance of observation, discussion, work samples and other more traditional forms of assessment of mathematical knowledge and skills. They are also reminded clearly that assessment should be an integral part of each child's learning and that the purpose of assessment is to facilitate this learning.

Mathematics Intervention, Victoria

In a similar way to the *Count Me In Too* program, *Mathematics Intervention* uses a particular clinical interview technique and instrument specifically constructed for the program (Pearn, 1998a; 1998b). This instrument — the Initial Clinical Assessment Procedure — Mathematics (ICAPM) — was devised initially in 1993 because it was felt that '... there was no comprehensive test available that allowed Grade 1 students to talk about their mathematical strategies and determined each student's place in the counting stages' (Pearn, 1998a, p.4). While not as extensive in its coverage as the SENA from *Count Me In Too*, the ICAPM is based on the same research and covers basically the same areas. Again, it is not the only assessment component of *Mathematics Intervention* and is complemented by a wide range of other techniques, including teacher's own observations in the classroom.

Flying Start, Tasmania

This program is designed to facilitate the achievement of the Key Intended Numeracy Outcomes (KINOs) (Department of Education, Community and Cultural Development, Tasmania, 1997) and its assessment is built around these outcomes and their associated developmental indicators. The KINOs for Year 2 are particularly relevant to this paper. Detailed indicators are given for each KINO at both the Kindergarten/Prep level and the Years 1/2 level, thus encouraging a developmental approach to their use. Further, the KINOs are designed to be numeracy outcomes rather than just outcomes in mathematics. That is, they involve not only the mathematical knowledge but the application of this knowledge in 'real-life' situations.

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Other programs/resources

There are numerous other programs which have relevance to the process of assessment of numeracy knowledge and skills in the early childhood years. The project *Assessing Literacy and Numeracy in the Early years of Schooling* (Curriculum Corporation, 1999) provides information to assist schools, teachers and education authorities to select early assessment tools consistent with their numeracy policies. The project report describes the wide range of approaches to entry assessment evident in schools in the States and Territories. Following the examination of both national and international assessment approaches, the report recommends some suitable materials for use in schools and systems around Australia. Others considering possible outcomes of learning in numeracy for children in prior-to-school settings include the *Foundation areas of learning* from South Australia (Department for Education and Children's Services, 1996) and *Early school assessment: Numeracy* (New South Wales Department of Education and Training, New South Wales Catholic Education Commission and Association of Independent Schools, New South Wales, 1998) from New South Wales. These are similar in many ways to the United Kingdom's *Nursery education desirable outcomes for children's learning on entering compulsory education* (School Curriculum and Assessment Authority, 1996). All of these have great potential to assist teachers in the prior-to-school years gain much better assessment data on their children's numeracy knowledge and skills. This data could then be shared with the children's school teachers, making it more likely that smooth transitions to school might occur.

As the children grow older, there are many numeracy assessment regimes which have been put into place. Some of these have already been noted. Others will only be mentioned here.

In 1995, the Queensland Government initiated *The Year 2 Diagnostic Net* (Metropolitan East Literacy Team, 1995) which was designed to assist teachers promote the effective teaching of literacy and numeracy.

> The Net involves a process in which teachers:
>
> - observe and map all children's progress using developmental continua for aspects of literacy and numeracy;
> - validate observations of children requiring additional assistance through specifically designed assessment tasks;
> - provide appropriate learning support to children by way of intervention programs;
> - report to parents about these aspects of children's literacy and numeracy learning and development (Metropolitan East Literacy Team, 1995, p. 1).

In Victoria, the Board of Studies has produced exemplary assessment tasks in mathematics for Years P – 2.

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> This publication shows teachers how assessment can be part of instruction to provide rich information to teachers on students' mathematical thinking, and to show how their performances and achievement can be interpreted in terms of the Levels of the Curriculum and Standards Framework (Board of Studies, 1995). Assessment information derived from these tasks can be used to guide subsequent teaching. It is also possible for these tasks to be used as tests at the end of a topic to indicate a student's level of understanding and what has been achieved (Board of Studies, n.d.).

The consultation on a preliminary draft of Early Stage 1 assessment (New South Wales Department of Education and Training, 1998b) in numeracy has been completed in New South Wales. This document, which is designed 'to assist teachers to make informed judgements about the numeracy achievement of students who are completing their first year of schooling' (p. 2) is closely linked into the Mathematics K – 6 Outcomes and Indicators (Board of Studies, New South Wales, 1998) where the early Stage 1 outcomes were originally presented. Again, these are designed to provide a learning and assessment framework in mathematics.

Similarly, South Australia has released its draft *School entry assessment: Planning for learning* which 'supports teachers to collect information about the knowledge and understandings children bring to school' and 'will support them to observe children's existing knowledge and skills in literacy and numeracy, as they start in the school setting, and to describe this using a common set of criteria' (Department of Education, Training and Employment, South Australia, 1998, p. 4).

Affective issues in the assessment of numeracy

As children develop their knowledge and skills in numeracy and are assessed in them, they also develop attitudes and dispositions (Yackel & Cobb, 1996). If children are going to have the confidence to take on the numeracy challenges which will confront them in their early years and later, they will need to sustain positive dispositions. Clarke (1988) has developed a simple inventory which can be implemented with young school children to ascertain how they feel about their learning. The tasks, suitable for school-aged children, which can be read by the teacher or the child, include the following:

- Write down the two most important things you have learned in maths during the past month.
- Write down at least one sort of problem which you have continued to find difficult.
- What would you most like help with?
- How do you feel in maths classes at the moment? (Circle the words that apply to you) a) interested, b) relaxed, c) worried, d) successful,

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e) confused, f) clever, g) happy, h) bored, i) rushed, j) Write down one word of your own.

- What is the biggest worry affecting your work in maths at the moment.
- How could we improve maths classes? (Clarke, 1988, p. 47)

Summary

Assessment is a major component of any teaching and learning program. The key purpose of all the assessment regimes discussed in this section of the paper is the improvement of the numeracy knowledge and skills of individual students and groups of students. In each case, the principles of meaningful assessment have been applied within the overriding context of early childhood education. As well, the assessment regimes have achieved the standards set by the National Council of Teachers of Mathematics that:

1. assessment should reflect... [what]... all students need to know and be able to do;
2. assessment should enhance... learning [by being an integral part of the planning process]
3. assessment should promote equity
4. assessment should be an open process
5. assessment should promote valid inferences about... learning
6. assessment should be a coherent process

(adapted from National Council of Teachers of Mathematics, 1995, pp. 9 – 22).

Technology and numeracy in the early childhood years

Over the last 15 years, there have been sporadic bursts of interest in the use of technology (here taken to mean electronic technology such as calculators and computers) in the early childhood years. The mid to late 1980s was a zenith for research and experimentation into the use of computers in early childhood education, both in prior-to-school and early school settings (Blemings, 1985; Campbell & Fein, 1986; Elliott, 1985; Porter, 1988) but it has not lasted. This is despite findings such as those reported in an analysis of research relating to young children's computer use, which noted 'improvements in mathematical understanding, expressive and receptive language development and also children's social-emotional development when computer-based learning experiences were combined with carefully structured adult assistance' (Fatouros, Downes & Blackwell, 1994, p. 57). In a recent survey undertaken in a group of prior-to-school settings in Sydney, it was

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found that fewer than 33% of the services responding had a computer available for children to use (Dockett & Perry, 1998). It would seem safe to say that the advent of computer technology has had little effect on the numeracy development of most children in prior-to-school settings (Hall & Elliott, 1993). However, this is not necessarily the case for children in the first years of school or for children who have access to computers at home.

One of the advantages of computer use by young children is that they are able to work at levels which are not constrained by their fine motor skills (Burgess & Trinidad, 1997; Clements, 1992). For example, pressing keys, rather than struggling with correct forms of notation, can mean that children focus on the nature of the task, rather than the ways in which it should be written. Technology is part of the lives of young children. On the basis that numeracy involves using 'mathematics effectively to meet the general demands of life at home, in paid work, for participation in community and civic life' (AAMT, 1997, p. 15), it seems reasonable that such technology should be an integral part of young children's numeracy experiences.

The creative potential of computer use with young children is noted by Yelland (1997) who suggests that 'the potential of computers to enable children to encounter and play with ideas has been increased over the past five years with hardware and software that allow the child not only to manipulate objects and ideas that are available in the real world but also to do things that are not possible' (p. 7). The use of open-ended programs, as indicated by Yelland (1997), can facilitate young children's involvement in problem-solving and collaboration, as well as forming the basis of an enjoyable experience which promotes feelings of confidence and competence (Clements, 1992).

The effect of electronic calculators on the numeracy education of young children has been much more profound than that of computers. In many ways, the advent of electronic calculators has changed the very nature of numeracy because of the ways in which they encourage experimentation, estimating and approximating. Quite a lot of work has been done in Australia by the Melbourne group led by Susie Groves (Groves, 1993; Groves & Cheeseman, 1992; Stacey & Groves, 1996) to show the value and nature of the calculator in early childhood mathematics lessons. It seems that the strengthening of the drive towards mental arithmetic (for example, McIntosh, 1996), has decreased the impetus for studies using calculators and supported a return to their use only when the basic operations have been mastered (Department of Education & Employment, United Kingdom, 1998). It is hoped that the value of the calculator as a learning and teaching tool is not lost to students in the early years of school.

In summary,

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> computers and other related technologies have become an integral part of our daily lives. They have altered our sense of people, space and time... So many aspects of the ways we communicate and handle information have been altered and will continue to be altered by technological development (Downes & Fatouros, 1995, p. 3).

It is not surprising that such experiences have a significant impact on the development of numeracy.

Professional development and initial teacher education in numeracy for early childhood teachers

As there is another paper which is devoted entirely to professional development and initial teacher education in numeracy, the issues will be treated only briefly here. However, there are some important points to be made.

Numeracy and reasons for people becoming early childhood teachers

Early childhood teaching, particularly in prior-to-school settings but also in the first years of school, is largely a female occupation. The negative links between women and mathematics have been documented by numerous authors (for example: Barnes & Horne, 1996; Forgasz & Leder, 1996). Hence, it came as no surprise to this author to be greeted one day by a student teacher with, 'What do you mean — I have to do two mathematics units! I chose early childhood teaching because I couldn't handle primary mathematics' (Perry, 1989, p. 139). It is not unusual for early childhood student teachers to have less than the equivalent of Year 12 mathematics and to have quite negative attitudes to the subject. Many early childhood teacher education programs do not alleviate this deficiency in experience, although they do try to work on improving the attitudes of these students. (In New South Wales, the major employer of school teachers, the Department of Education and Training, insists that any teacher seeking employment in Departmental primary schools has a minimal standard of Year 12 mathematics.) Very few early childhood teacher education programs in Australia meet the time allocations recommended by the Discipline Review of Teacher Education in Mathematics and Science (Speedy, 1989).

Hence, it is not surprising that many early childhood teachers feel much more at home with literacy than with numeracy and, as a consequence, concentrate more on literacy. To alleviate this feeling of inadequacy or to strengthen the already strong commitment to mathematics which is held by some early childhood teachers,

> ...early childhood mathematics teacher education courses must involve their students learning mathematics. That is, the students need to be involved in

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> creating significant mathematical ideas in a manner which will allow them to experience the excitement and joy which... they will help engender in their children....The type of mathematics introduced in these courses is critical, particularly for those students for whom school mathematics does not carry fond memories. 'More of the same' is not likely to produce the desired learning nor attitudes which are positive towards mathematical learning (Perry, 1989, p. 146).

Characteristics of effective professional development in numeracy for early childhood teachers

The characteristics of effective professional development are common across all subject areas because they have to do with the general process of learning rather than the particular features of the material being learned. A recent New South Wales wide evaluation of early literacy highlighted key features of exemplary professional development programs in early literacy. There seems to be no reason to suggest that these features would not hold true for early numeracy professional development. The features are:

- funds are directed to these programs
- there is a clear focus to the programs, often building on past programs and extending programs over several years
- more than one school/educational setting is involved
- the beliefs, understandings, expectations and practices of teachers (and in some cases, parents) are challenged
- opportunities for the classroom application of new or different approaches and the reflection and evaluation of these efforts are incorporated
- there is a coherent theoretical and philosophical base which informs classroom application
- time and opportunities are provided for teachers to develop collegial ties with other teachers both within and beyond their own school
- mentoring and other forms of support within and beyond the school are used to maintain the programs.

> Each of these features is important, yet it is in combination that they lead to a professional development program likely to influence teacher thinking and practice, school culture and student learning outcomes (Dockett, Perry & Parker, 1998, pp. 203–204).

In summary, for the particular case of numeracy, there is a need for professional development to address:

- teachers' understanding of their own mathematics
- teachers' understanding that mathematics teaching is problematic

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- teachers' understanding of what constitutes effective mathematics teaching
- the development of a rich sense of what comprises numerate behaviour and how mathematics and other curriculum areas might contribute to it.

The Senate Employment, Education and Training References Committee (1996) notes that, since the emergence of subject specialists who are responsible for professional development across a range of grades (for example, K–6 or K–12), there are fewer early childhood specialist consultants within education systems. While this is not the only reason for the decline, the result is often a neglect of the early childhood area as a whole, although all States and Territories have targeted the early school years in specific areas, particularly literacy and numeracy.

In prior-to-school settings, there is a number of other issues which must be considered in the context of professional development of staff. Different employers, different industrial awards and different licensing requirements can mean that professional development in prior-to-school settings is often either unavailable or haphazard. This is exacerbated by issues such as lack of funding for release of licensed staff and the geographical isolation felt by staff in small centres, particularly in rural areas.

Turnover of staff in early childhood settings and the effect of this on professional development

One of the aspects of the early childhood field which makes professional development problematic is the relatively high level of staff turnover, particularly in prior-to-school settings (Wangmann, 1995). The effect of a professional development program can be severely diminished if staff leave the setting before they are able to either implement changes arising from the professional development initiative or, at least, pass them on to colleagues. In the high stress field of early childhood, unfortunately this scenario is played out all too often (Senate Employment, Education and Training References Committee, 1996), thus diluting the effect of what often are highly effective professional development schemes.

Overall summary

This paper aims to establish the significance of the early childhood period in children's numeracy development. By outlining the general principles underlying young children's learning at this time, it seeks to highlight the characteristics of young children and appropriate educational responses to these. Several innovative and exciting projects aimed at enhancing children's early numeracy development are

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highlighted, and the elements of such programs are discussed. Several themes recur in the discussion, and are worthy of emphasis in conclusion.

- Early childhood numeracy does not occur only in school contexts — much has happened, albeit often on an informal or incidental basis, before children come to school. Programs which are effective in promoting numeracy among young children recognise this and aim to build upon it. It seems clear that one way to enhance numeracy outcomes for young children would be for those involved with children in the prior-to-school years — parents and teachers — to work together with those in school settings. This proposal does not imply that school curricula have a place in prior-to-school settings. Rather, it suggests that there is much to be gained in terms of a planned approach to numeracy development, in relation to establishing children's numeracy interests, understandings and dispositions and exploring the contexts in which they operate, by working together.
- Early intervention (or simply, 'effective' teaching) in early childhood settings has the potential to enhance the numeracy development of many young children. However, the quality of the intervention and the follow-up provided are critical to this outcome.
- Planning for numeracy in the early years can take many and varied forms. Such diversity is to be encouraged, as teachers, parents and school communities respond to the needs, strengths and interests of their children.
- Assessment in numeracy needs to recognise the complexity of mathematics learning as well as the responsibility of teachers to engage in an ongoing process of assessment, with the aim of informing further learning and teaching.
- The impact of technology on the lives of young children, and its subsequent influence on numeracy, cannot be ignored.
- While again reiterating the danger of pushing down the primary curriculum, there is a need for early childhood teachers to develop and enhance their own competence and confidence in mathematics and to use this to plan appropriate in-depth numeracy learning experiences for young children. Closer links between teachers in prior-to-school and school settings could facilitate this.

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